A Data-Driven Approach for Granular Simulation of Potential Earthquake Damage to Bridge Networks and Resulting Decreases in Mobility

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Collect Structure-Specific Metadata

By harvesting data from publicly available sources, locations of bridges in a region as well as their essential structural and geotechnical properties, and hazard exposure can be extracted. This data is crucial in image-based modeling procedures, given images are best utilized for geometry and material-type extraction, hence they provide only a part of the data necessary for constructing detailed structure-specific models. ShakeReady database, currently under development, contains a collection of bridge data obtained from web-based resources (Figure 1).

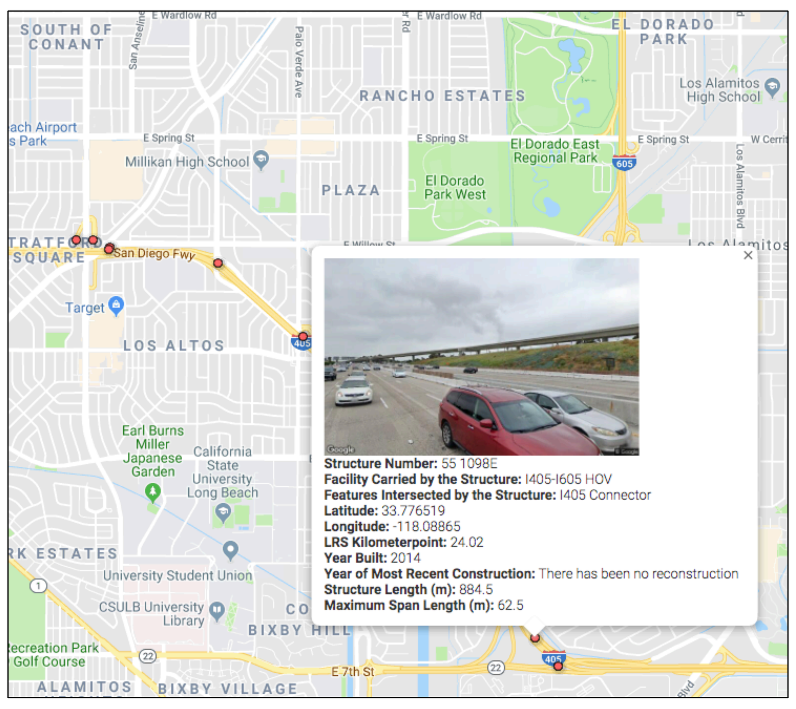

Figure 1. A snapshot from the user interface for ShakeReady database

Create Structure-Specific Geometric Models

The geometry of bridge structures can be reconstructed with exceptional accuracy using a combination of image processing and computer vision techniques. This step requires fusing satellite and street-level imagery. Satellite imagery is used to determine the bridge centerline. Street-level images are utilized to obtain dimensions of the structural members and in-span hinge locations. Deck superelevation is back-calculated from posted speed limit information. Figure 2 shows the image-based geometric model for a 16-span bridge and its street-view image from the same viewing angle.

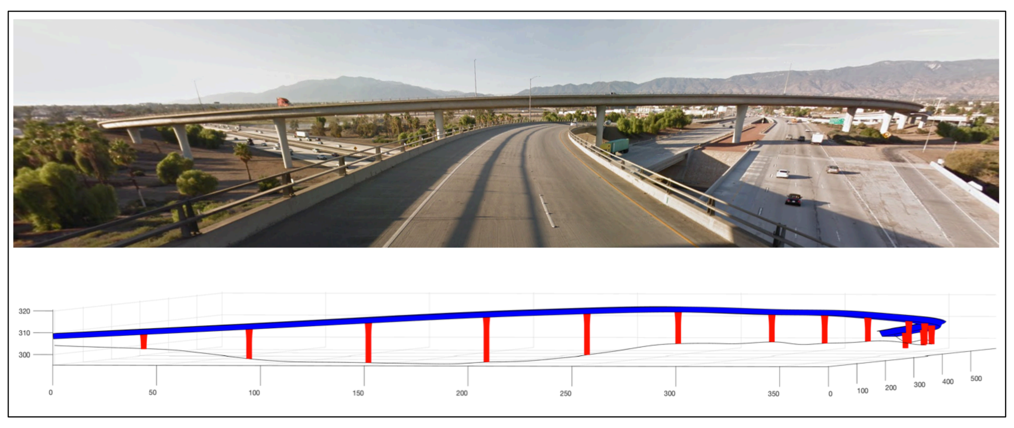

Figure 2. A street-view image (top) and the image-based geometric model (bottom) of the 16-span I-10 W/I-215 interchange bridge

Generate Structural Models with Class Statistics for Structural Properties and Compute Fragility Functions

Geometric models are populated with structural properties through component class statistics existing in the literature. Then, structure-specific fragility functions are computed based on appropriate component damage thresholds. In California, most class statistics are dependent on the era in which a structure is built (obtained in Step 1). Figure 3 shows a comparison between the collapse fragility functions of the structure displayed in Figure 2 when modeled using as-built drawings versus image-based geometry populated using class statistics.

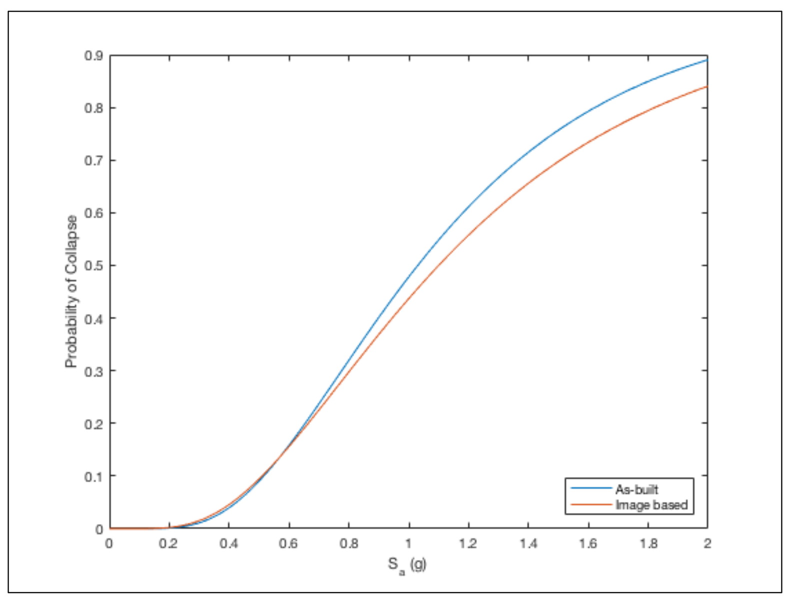

Figure 3. Collapse fragilities for the structure displayed in Figure 2 obtained by modeling using as-built drawings versus image-based geometric models populated with class statistics

Estimate Infrastructure Damage

Once intensity measure maps resulting from a scenario earthquake are coupled with fragility functions, the probability of exceeding the damage levels defined in Step 3 can be computed. By combining these probability measures with restoration functions, overall functionalities of all bridges within a network can be determined. Subsequently, bridges below certain functionality levels can be considered unsuitable for vehicle traffic due to seismic damage. Figure 4 shows the bridges expected to remain closed 30 days after the M_w 7.2 Palos Verdes scenario earthquake.

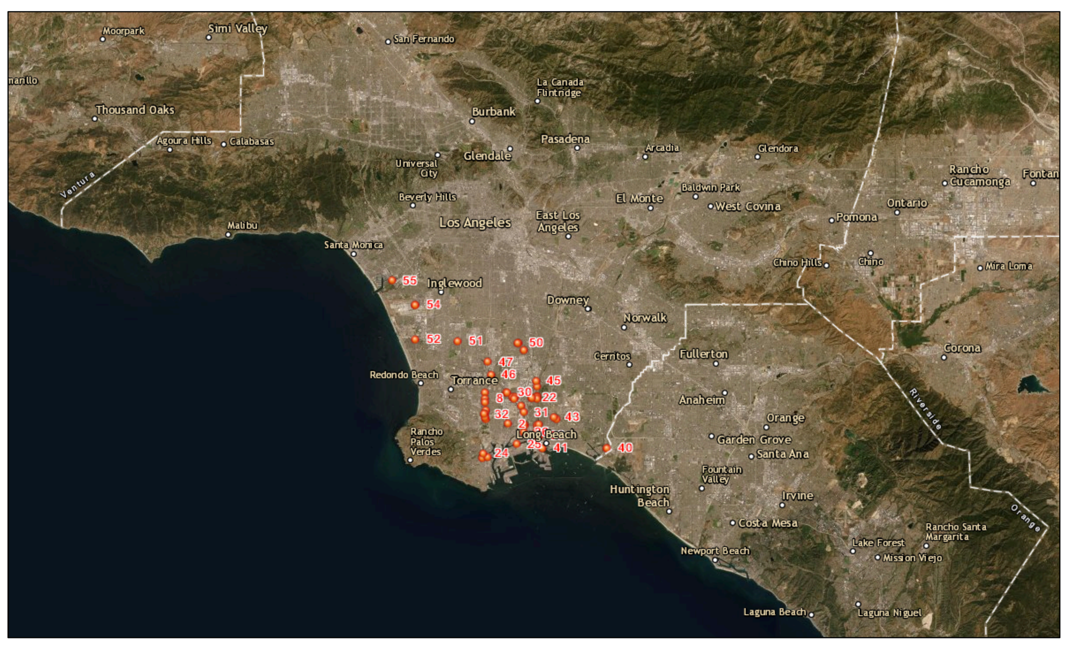

Figure 4. Expected bridges closures due to M_w 7.2 Palos Verdes scenario earthquake 30 days after the event

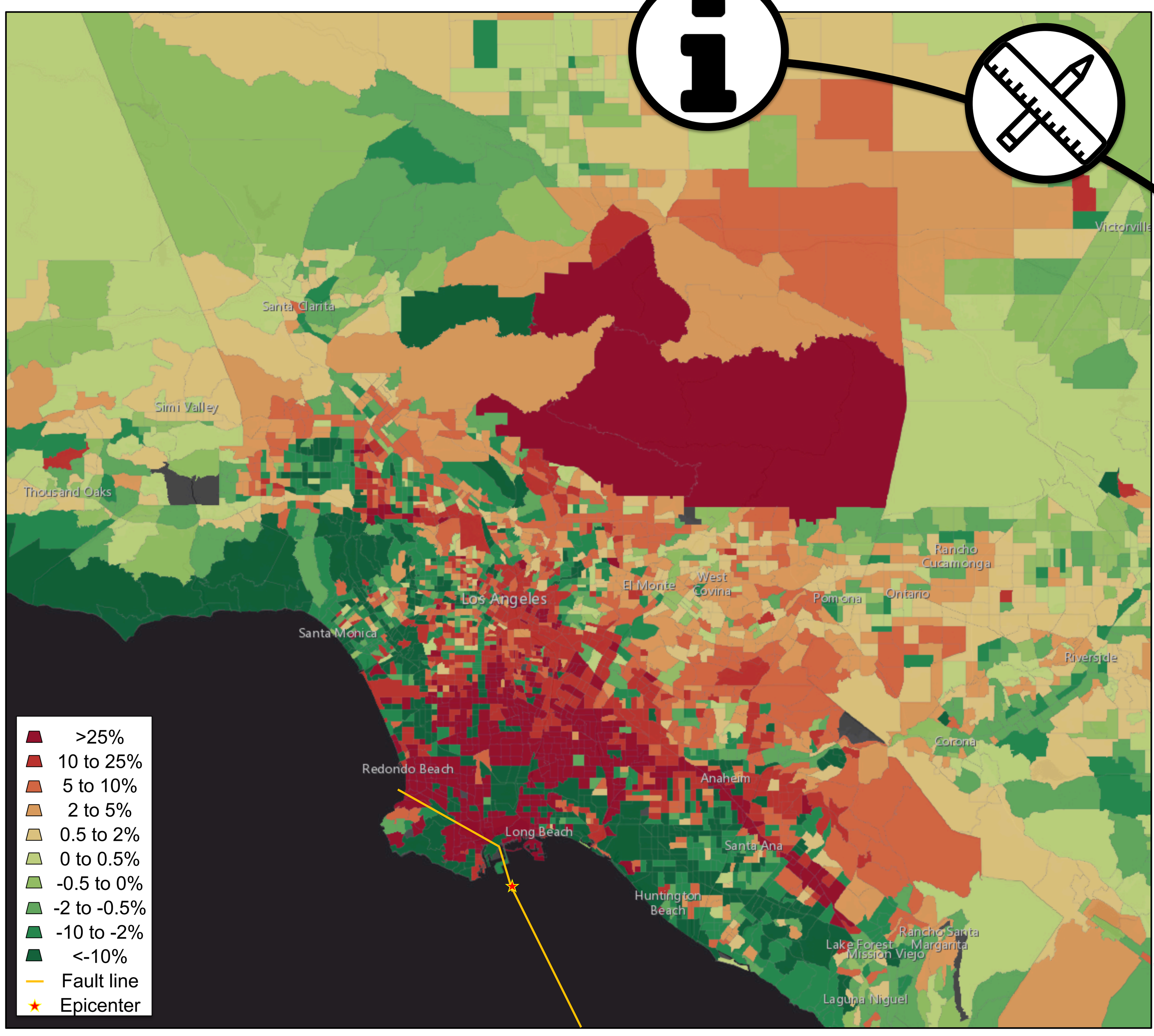

Figure 6. Percent increase in heavy duty truck traffic in Los Angeles area 30 days after the M_w 7.2 Palos Verdes scenario earthquake

Couple Damaged Network with a Regional Transportation Model

Bridge closures due to an earthquake can be modeled by removing the links associated with closed bridges from the regional transportation network (e.g., Figure 5) and simulating the resulting traffic behavior. This allows for the investigation of increasing travel costs in traffic assignment. Figure 6 shows the anticipated percent increase in heavy duty truck traffic in Los Angeles at traffic analysis zone-level 30 days after the Mw 7.2 Palos Verdes scenario earthquake.

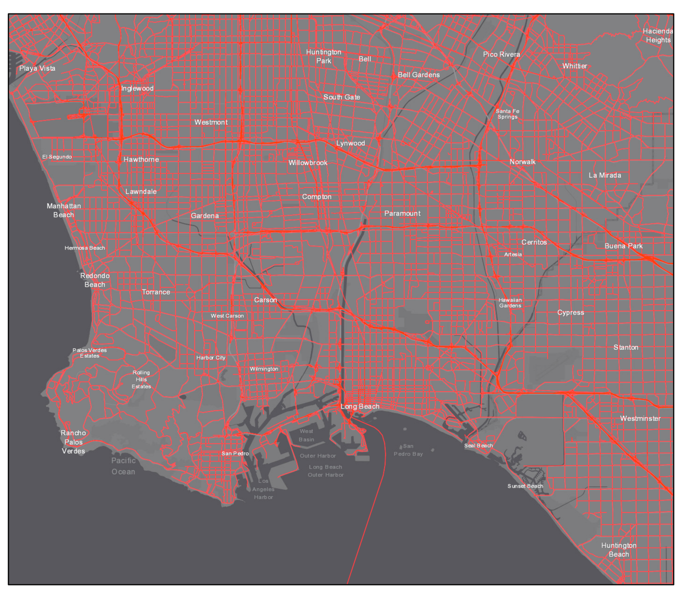

Figure 5. Transportation network for the area around Port of Los Angeles

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